



Design & Development of A Large Li-ion Battery Pack for EVs

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EVS-24

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Stavanger, Norway

About EnerDel



www.ener1.com

NASDAQ: HEV



EnerDel

www.enerdel.com



enertech

www.enertechint.com

EnerFuel

www.enerfuel.com

NanoEner

www.nanoener.com



❖ **EnerDel – Engineering & Cell Mfg. Facility** **Indianapolis, IN**

- ❑ Established in October, 2004 as a JV between Ener1 Lithium Group and Delphi Lithium Group
- ❑ Develops large format Li-Ion batteries, 92,000 sq. ft including 68,000 sq. ft plant and ~6,000 sq. ft. dry room
- ❑ 135 Employees



❖ **EnerDel – Pack Mfg. Facility** **Noblesville, IN**

- ❑ 35,000 sq. ft of manufacturing and general purpose office area
- ❑ Dedicated to battery pack assembly and testing
- ❑ ~60 employees



❖ **Enertech - Chungbuk, Korea**

- ❑ 89% equity stake
- ❑ 8 years of production experience with locations in Seoul (Office) and Chungbuk (Mfg.), ~300 Employees, ~ 200,000 ft² Mfg area
- ❑ 3rd largest lithium-ion battery producer in Korea. ~ 2M consumer cells/mo
- ❑ Production capacity of 15,000 EV battery packs a year.

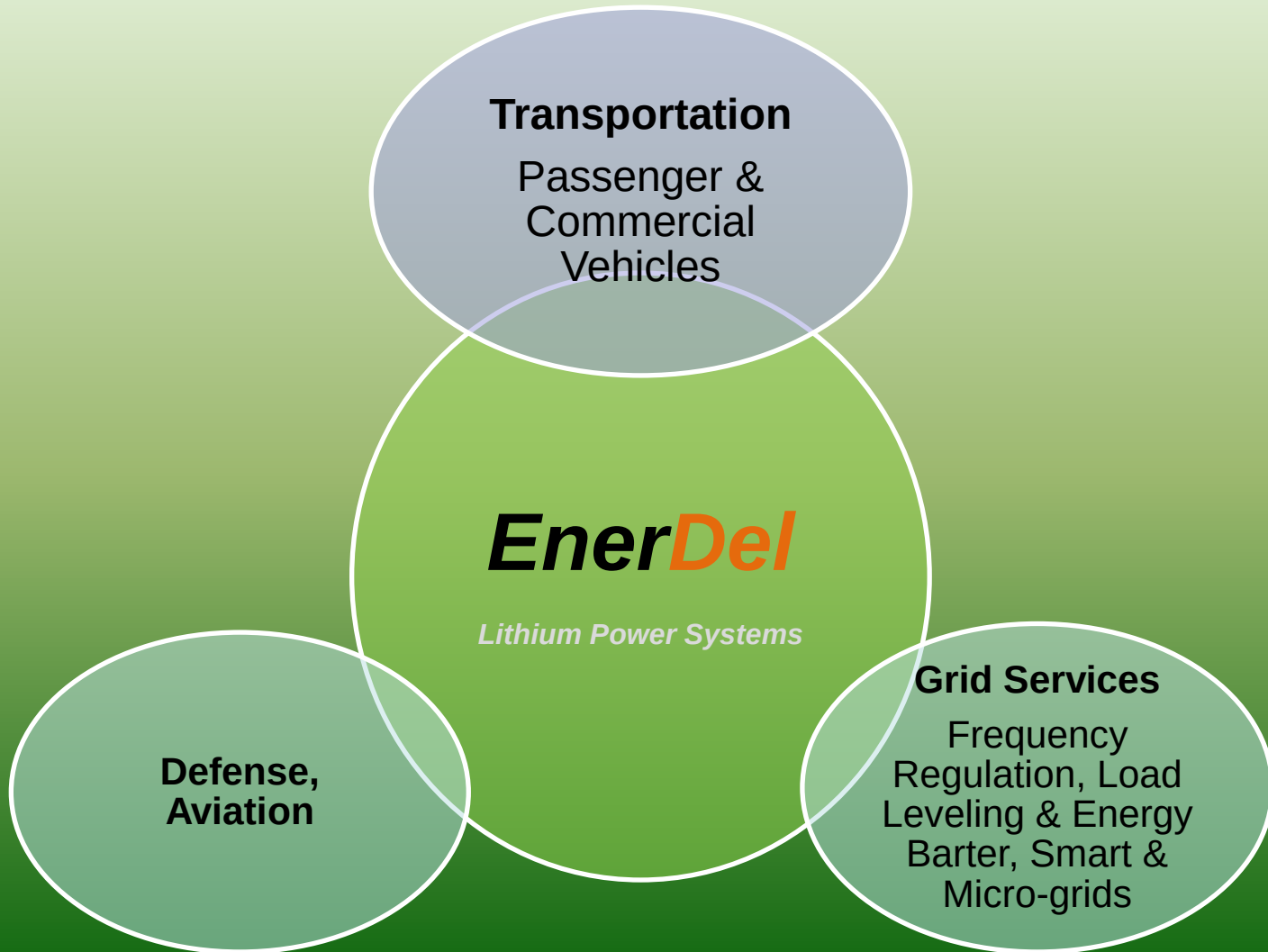


(R&D, Cell, Pack & Admin. Div.)



(Electrode Division & new building)

EnerDel's Market Focus



Performance

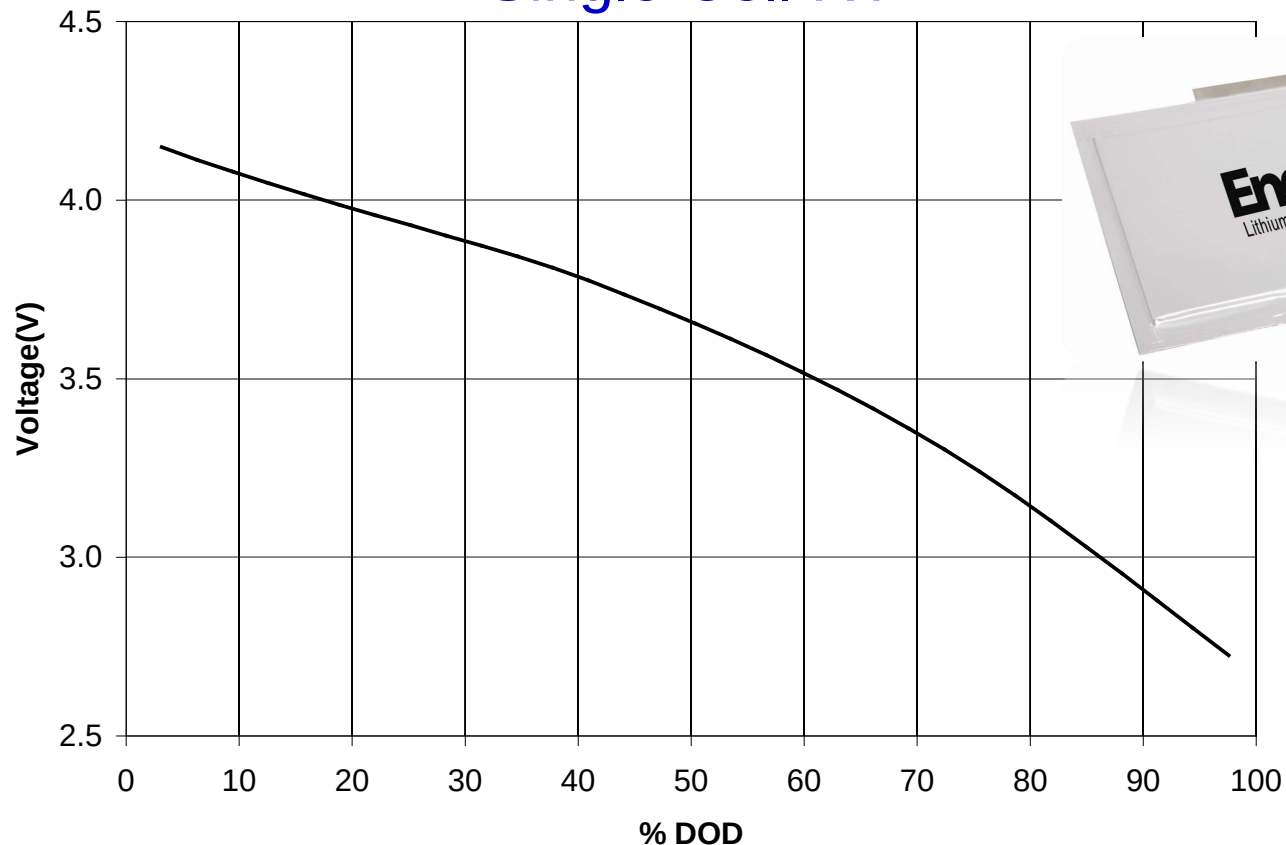
High Energy Cells: NMC Oxides/HC



Description	Specification
C/1 Discharge Capacity	18.5 Ah
Max Voltage on Pulse Chg.	4.1V
Min Voltage on Pulse Dchg.	2.5 V
Energy (C/1 @RT)	65 Wh
10s Pulse Power (Specific)	Up to 4kW/Kg
Energy (Specific)	150 Wh/Kg
Dimensions (WLT)	147mmx234mmx5.8mm
Weight	425 g
Volume	0.2 L
Operation Temp. Range	-25° C to + 52° C

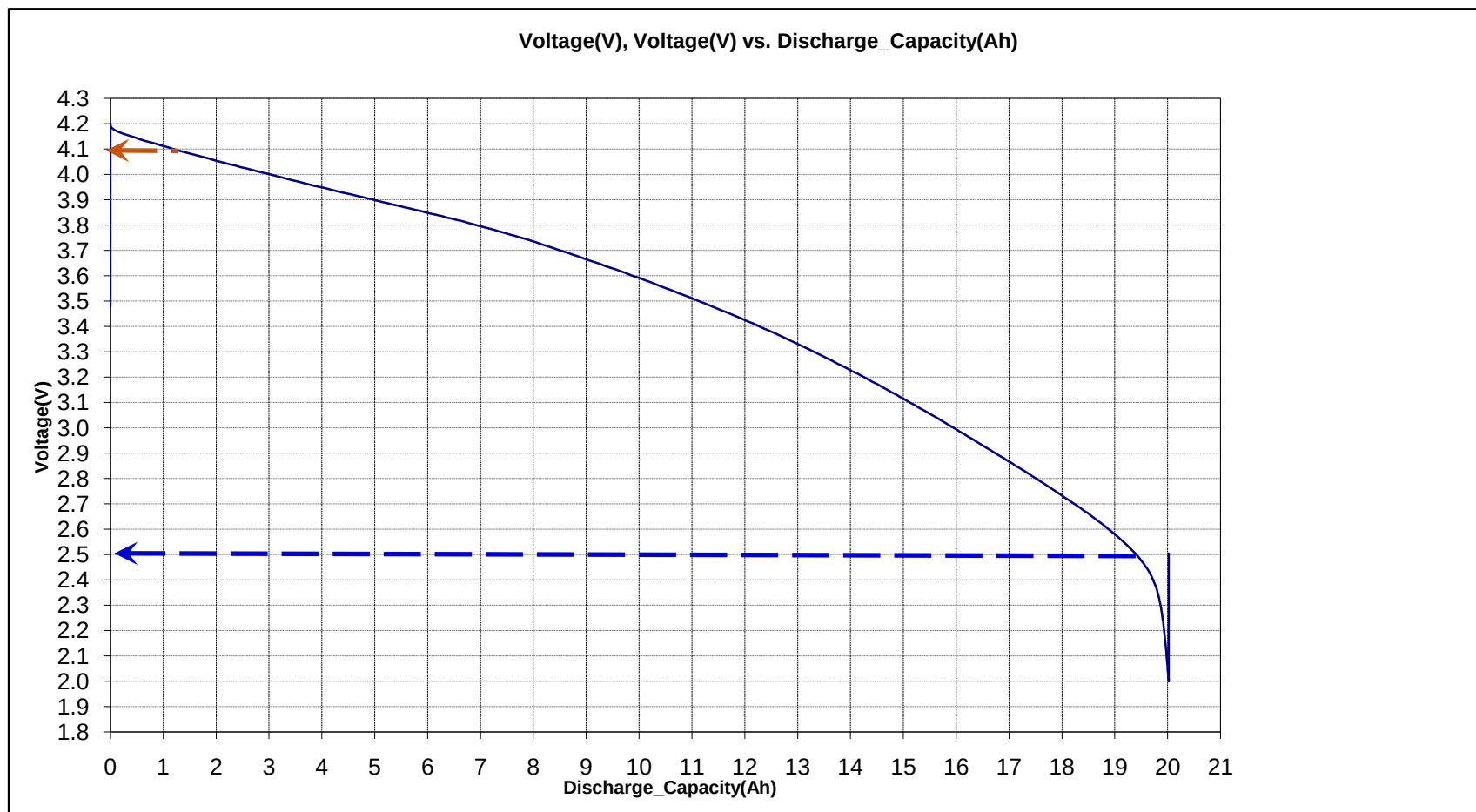
Voltage Profile vs. DOD

Single Cell RT



- Voltage profile is neither flat nor sharp voltage fall off

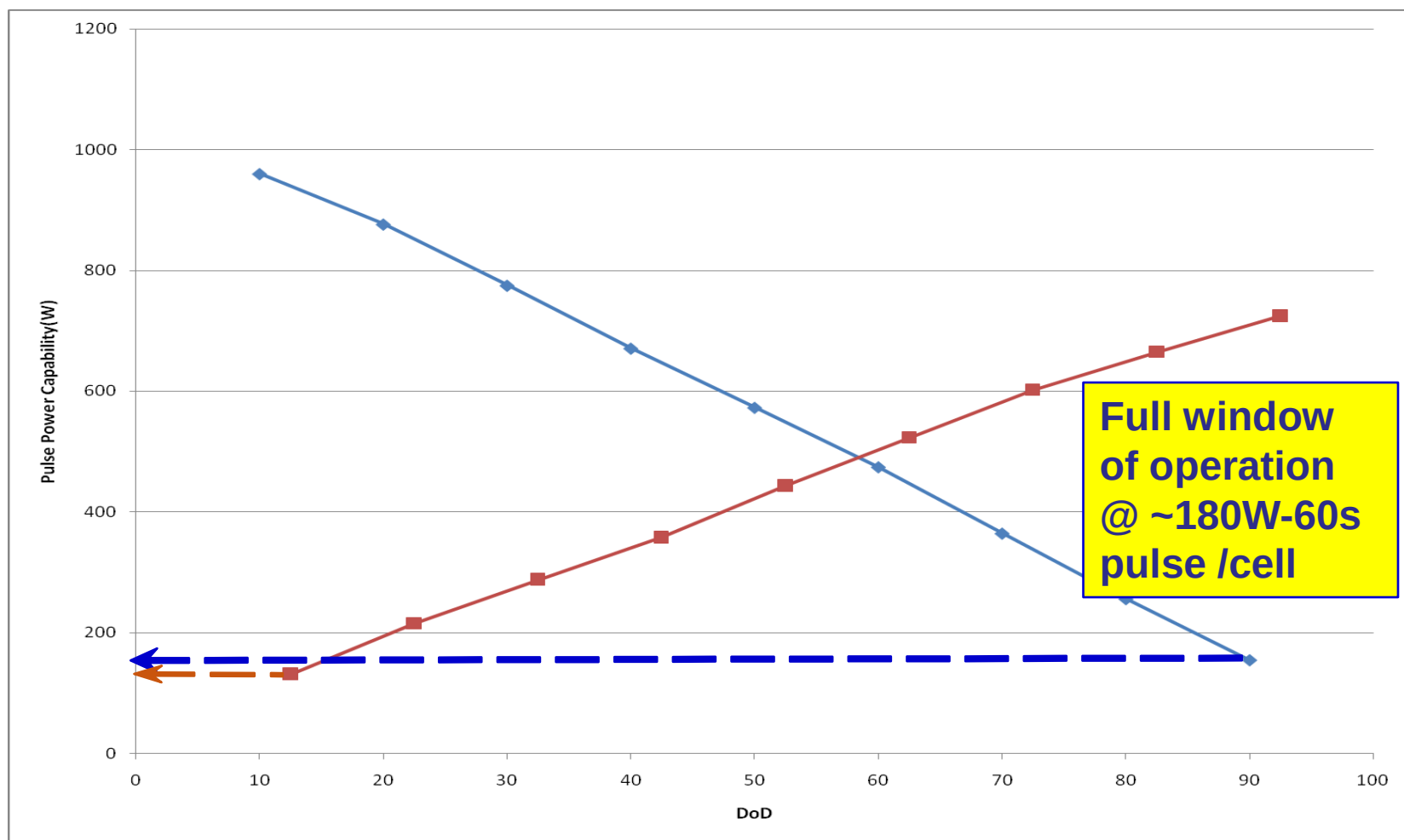
Voltage Profile (vs. Capacity Removed)



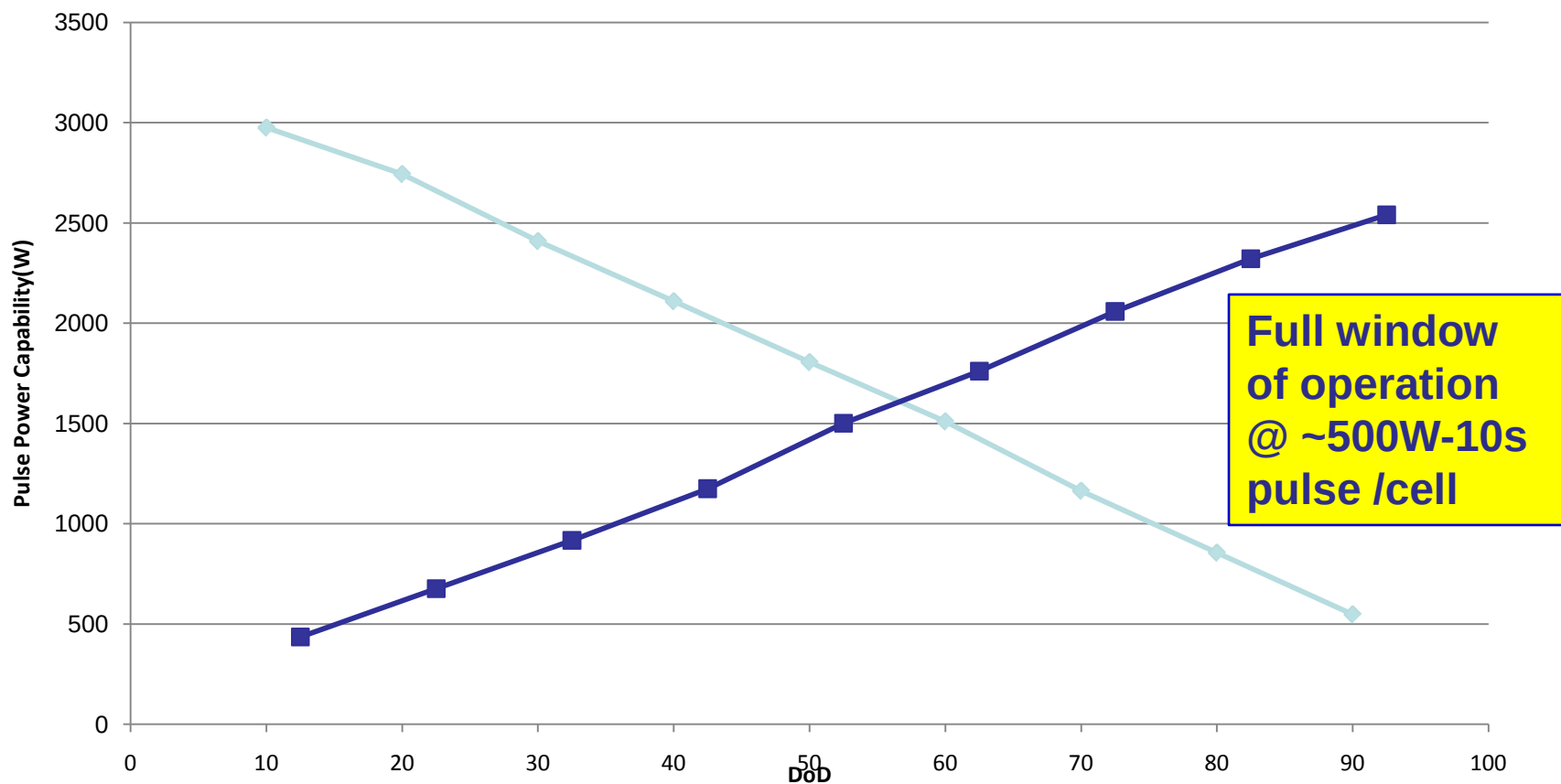
Pulse Power & Available Energy

- **Pulse power capability is a function of:**
 - ❑ **Pulse duration (2s, 10s, 30s, 60s)**
 - ❑ **Operating temperature**
- **The ability to provide required pulse power determines the available, aka usable, energy**

60s Pulse Power Characterization (RT)

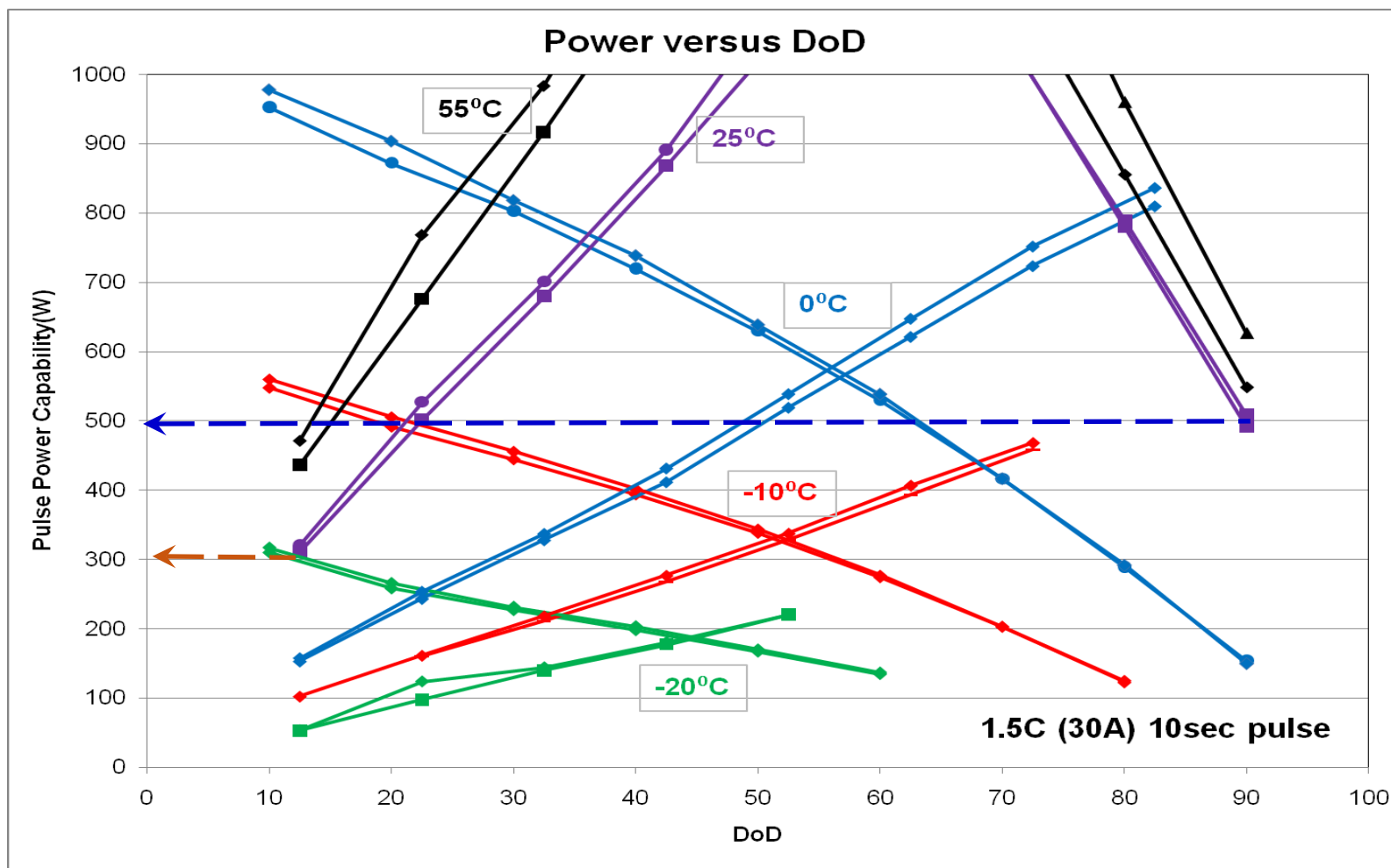


10s-Pulse Power Characterization



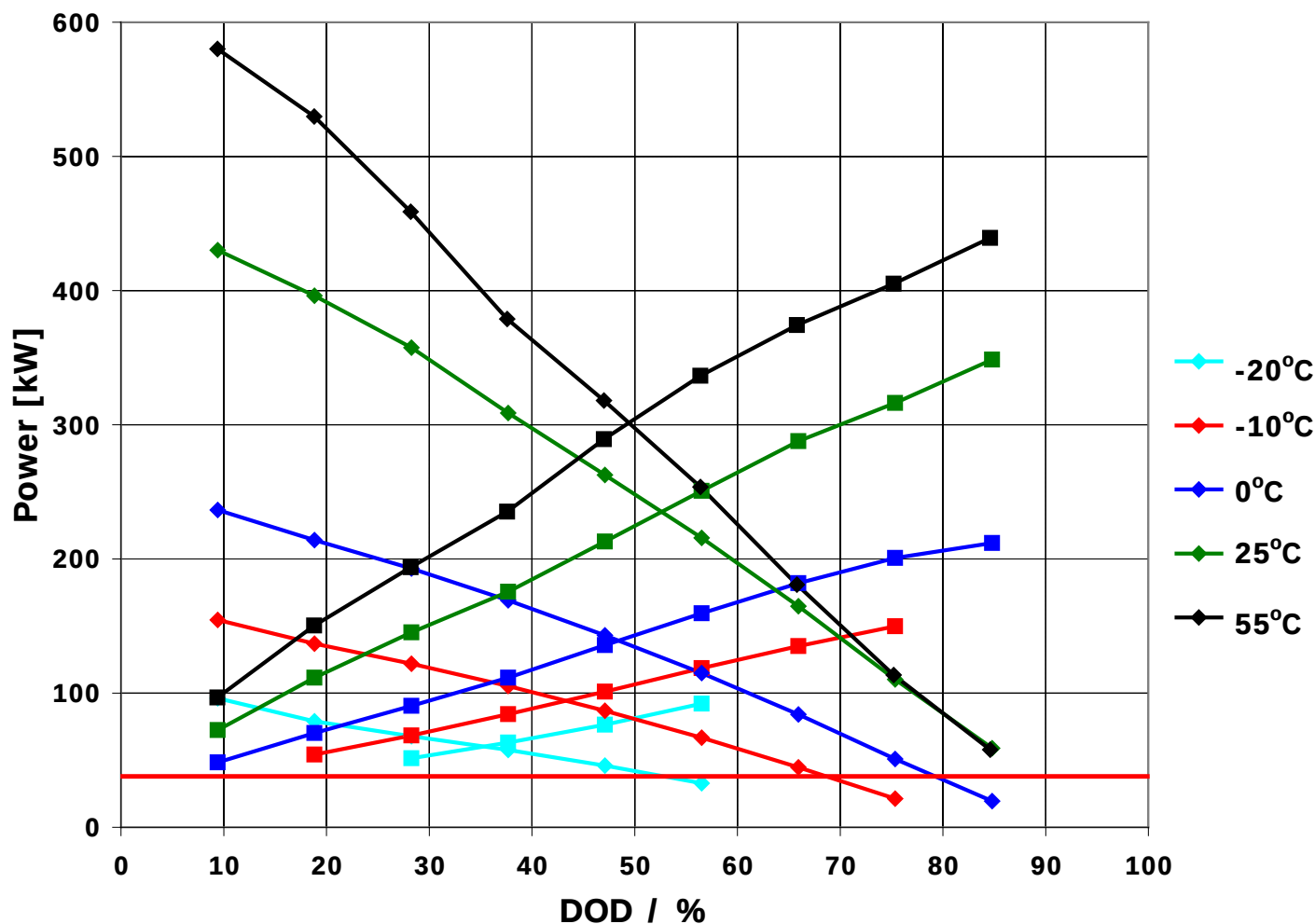
Performance Characterization @ Temperatures

10s Pulse Power Characterization

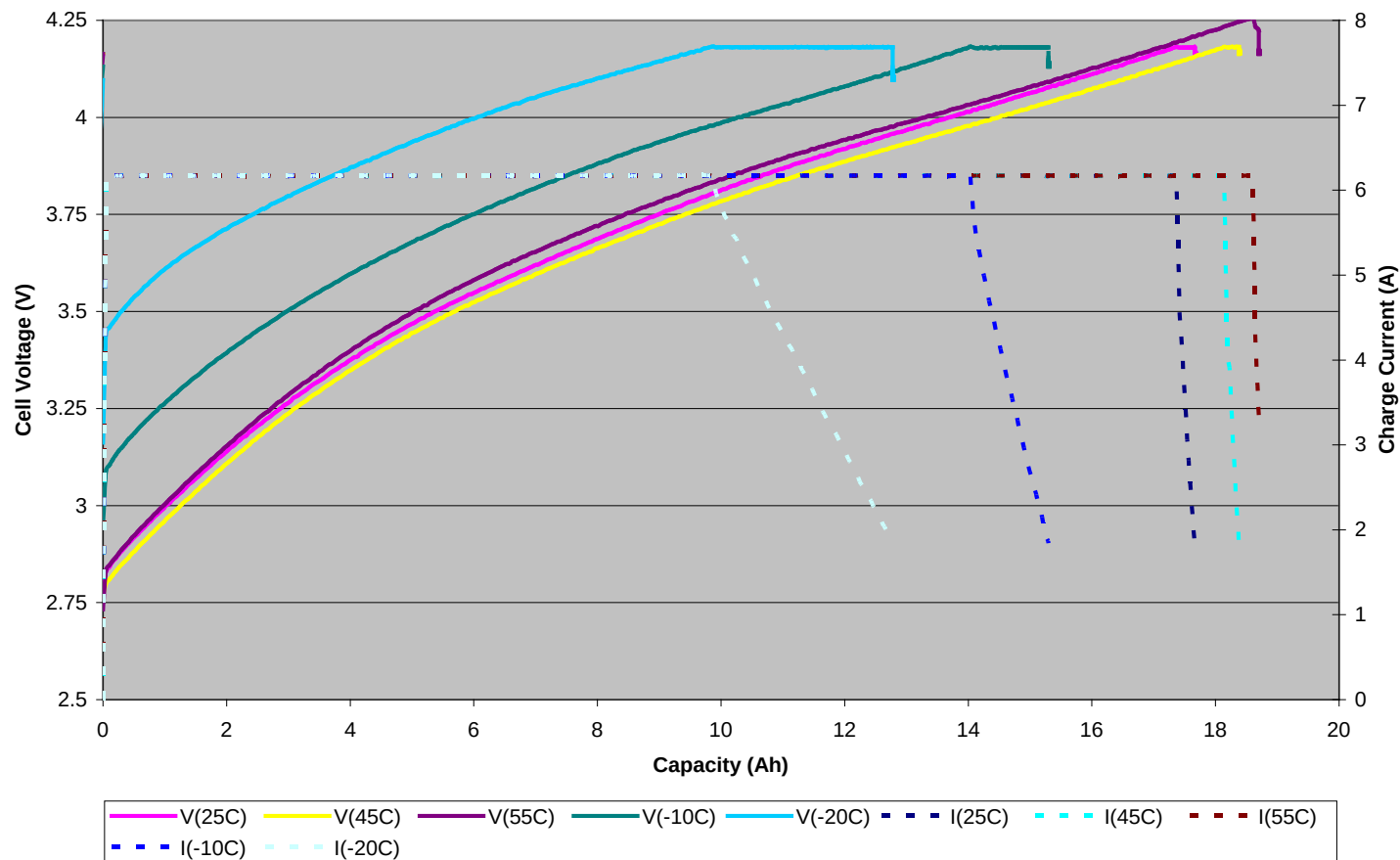


60s HPPC Power @ Various Temperatures

26kWh Think! Pack



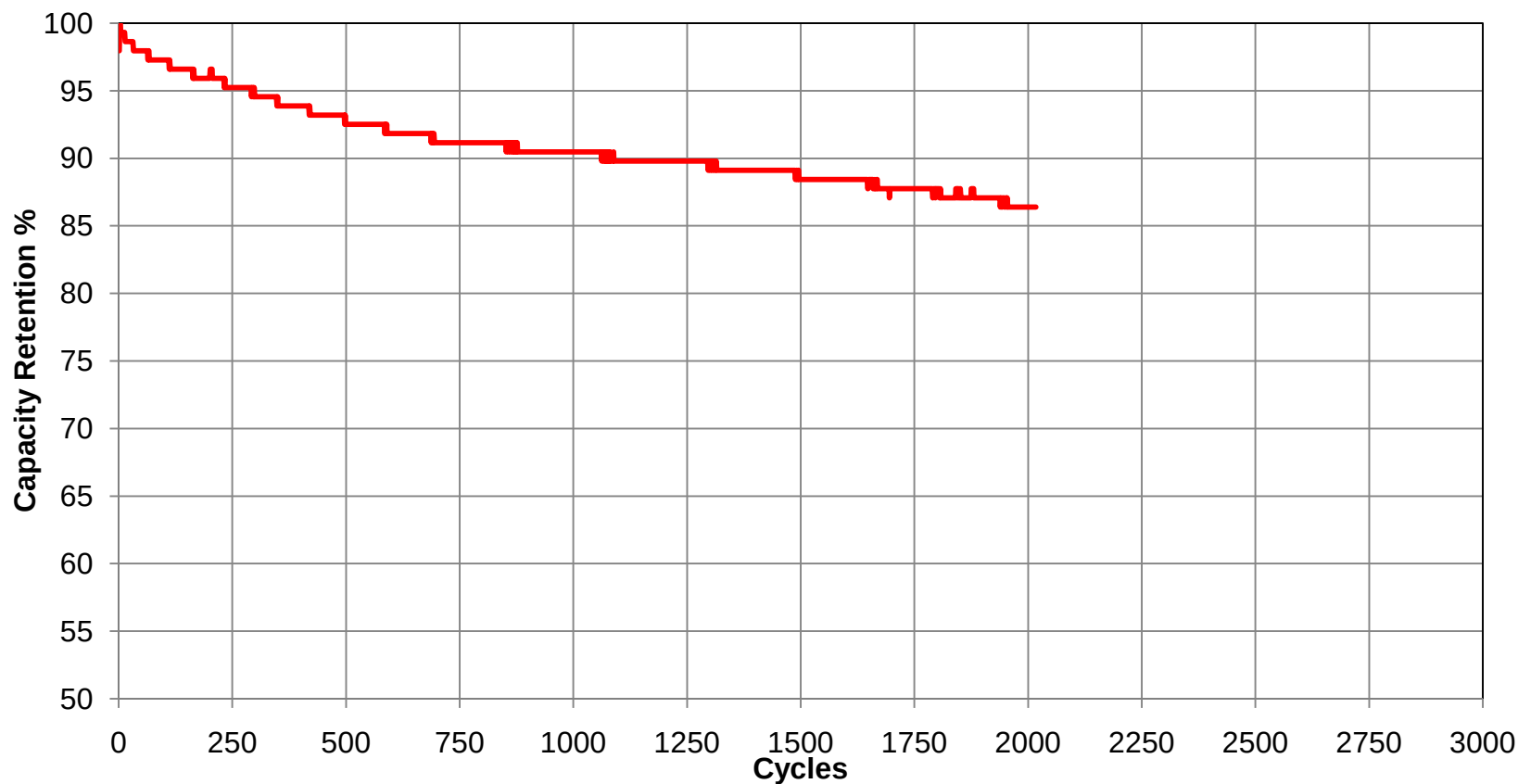
C/3 Charge @ Temperatures



Life

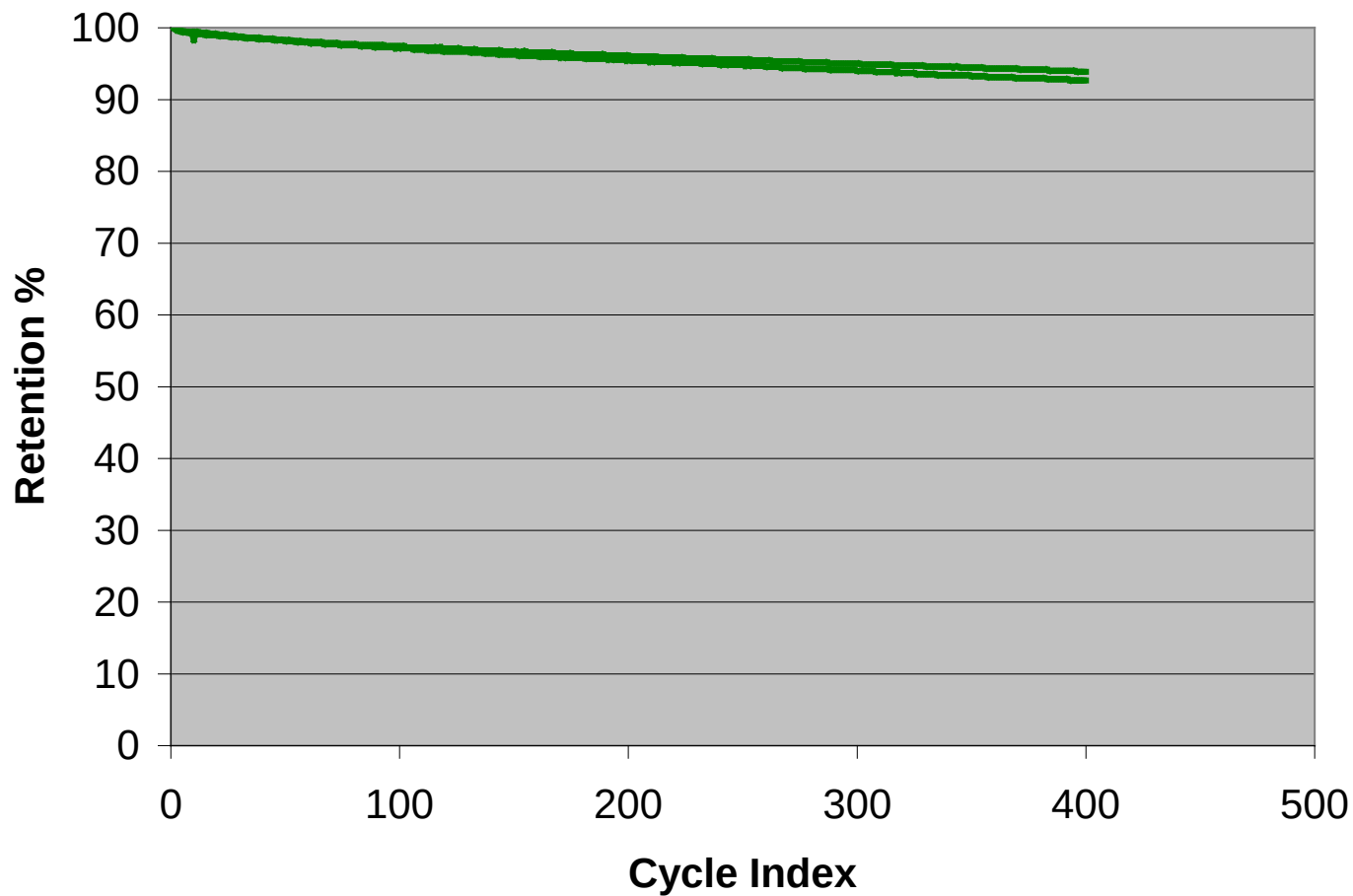
Accelerated Cycle Life

18.5Ah, 2C/2C Full DOD, 30°C



- > 86% of initial capacity remaining after 2,000 Cycles

Accelerated Cycle Life
18.5Ah, 1C/1C Full DOD, 55°C



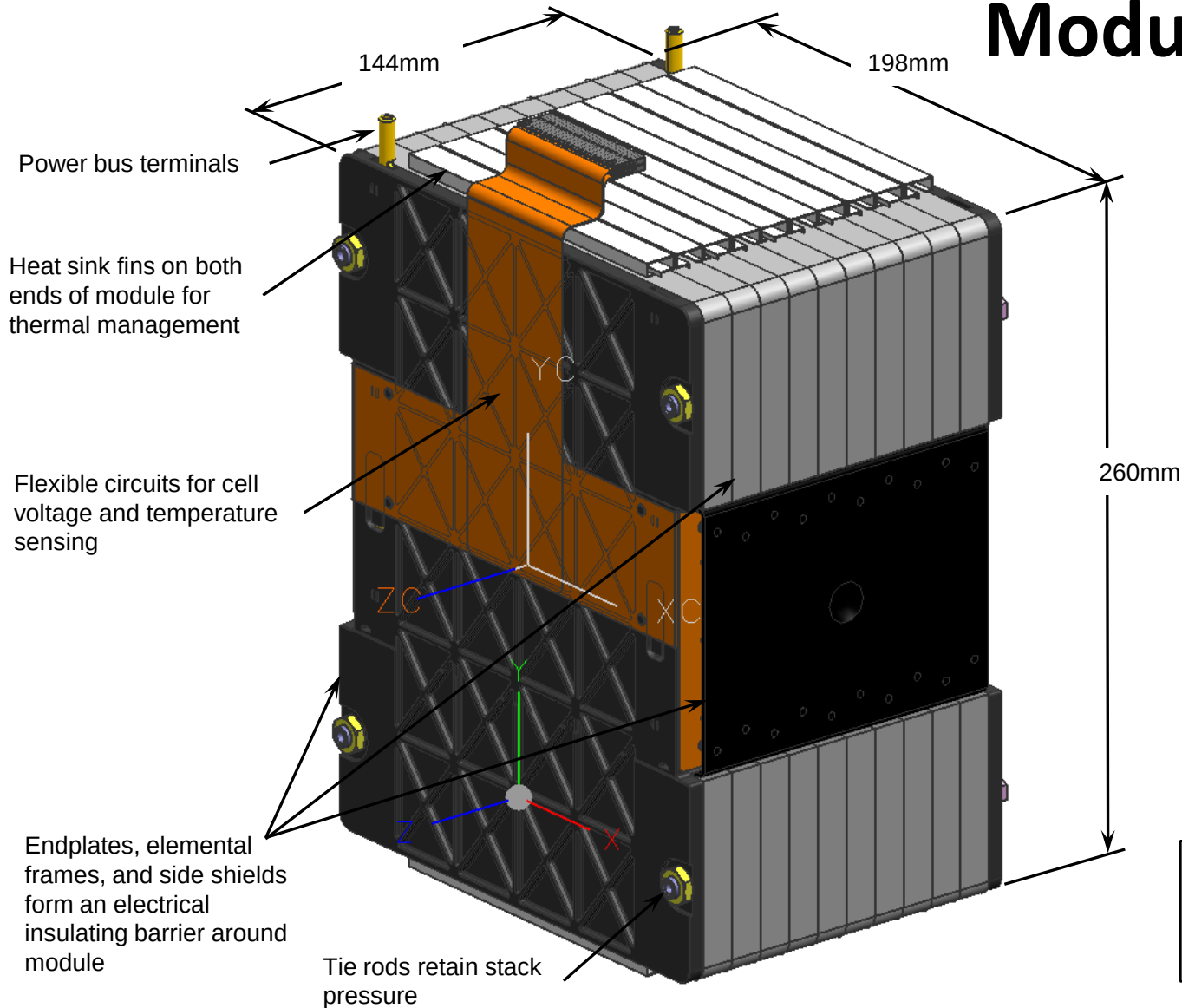
Pack Construction and Assembly

Modular Design



EnerDel - Pack Arrangement - Quantity							
	Cell	Element	Module	Sub Pack	Pack	Cells in Series	Cells in Parallel
Cell	1						
Element	2	1					
Module	24	12	1				
Sub pack	48	24	2	1			
Pack	384	192	16	8	1	96	4

Module Assembly



EnerDel prismatic cell

Module Details

- 1 Module = 10 Elements
- 1 Element = 2 Cells
- TOTAL CELL COUNT = 20 CELLS

Full EV Pack Specification

EnerDel provides a complete turnkey system

Description	Full EV Pack
Configuration	96s4p
Modules /Subpacks /Cells	16/8/384
Min. Pulse Voltage	240 V
Max Pulse Voltage	400 V
Nominal Capacity	74 Ah
Total Energy	26 kWh
Volume	222 Liter
Mass	285 Kg
Cooling	Forced Air
Specific Energy (pack level)	91 Wh/Kg
Energy Density	117 Wh/l



Abuse Tests Characterization

		Hazard Level							
		0	1	2	3	4	5	6	7
loss of functionality		X							
defect			X						
leakage				X					
venting					X				
fire or flame							X		
rupture								X	
damage			X						
repair of protection device needed		X							
irreversible damage, repair needed			X						
reaction or thermal runaway					X				
electrolyte loss				X					
electrolyte loss > 50%					X				
flying parts								X	
ejection of active mass								X	
explosion									X
disintegration									X
		accept				reject			

Key: Characterization Code for Hazard Severity

Module Overcharge Test

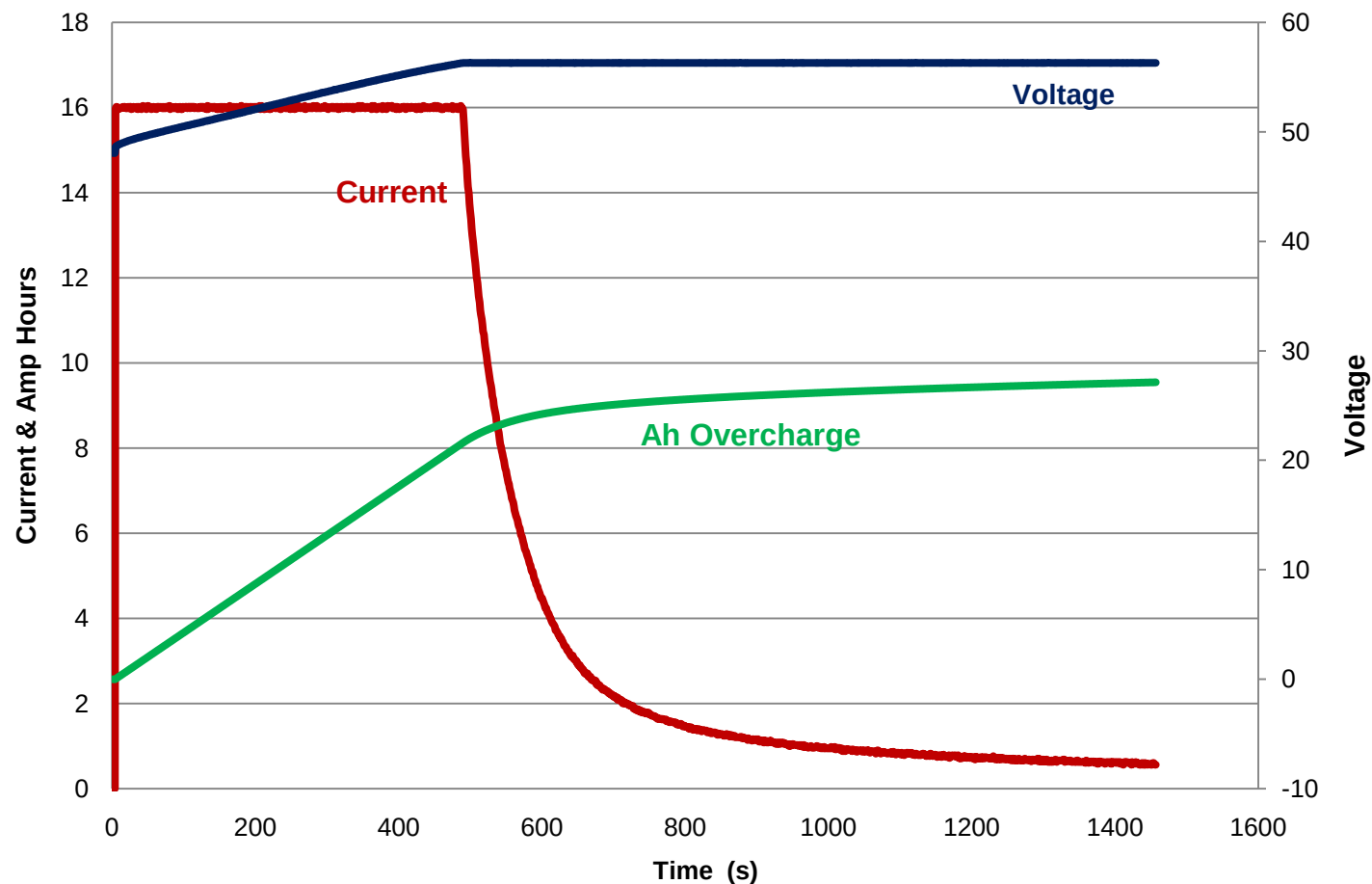
➤ **USABC-ESS Abuse Test Proc. Sec. 4.3**

- ❑ 48.5V, 37Ah Module charged to 100%SOC, RT
- ❑ Overcharge at 32 Amps-CC
- ❑ Test Constraints:
 - SOC limit of 200%
 - Voltage limit of 450V (pack-level)
 - 4 hours time limit

➤ **Resulting Severity Level:**

- ❑ 3 (No smoke, no fire, no explosion)
- ❑ Max module temp. 29°C

A306 Overcharge Module



Nail Intrusion Test

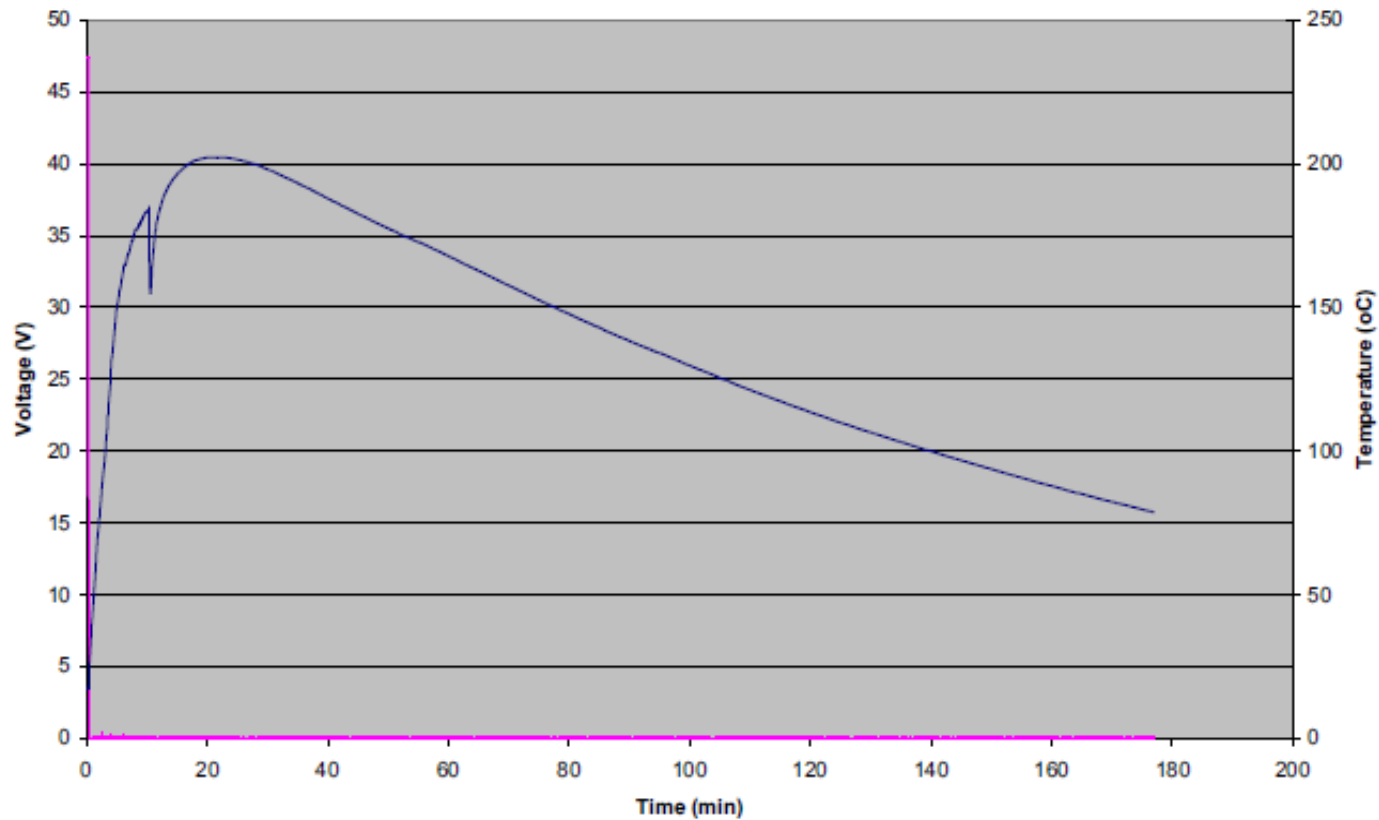
➤ Test Description

- ❑ 48.5V, 37Ah Module charged to 100%SOC, RT
- ❑ 25mm rod with pointed end fully penetrating
- ❑ Ram speed at about ~1 inch/s – Test wait out 3 hrs
- ❑ Total displacement of 14.5 inches
- ❑ 2 orientations, perpendicular & transverse to the electrode plates
- ❑ 2 positions, centered and offset

➤ Resulting Severity Level:

- ❑ 4 (electrolyte leak, smoke, no fire, no explosion)
- ❑ Max module temp. 202°C

Module Voltage & Temp. Profiles



*Thank you for your
attention*